Assessing efforts to reduce the environmental impacts of carbon fibre composites in vehicles

Frida Hermansson*, Matty Janssen, and Magdalena Svanström

Chalmers University of Technology, Department of Technology Management and Economics, Division of Environmental Systems Analysis

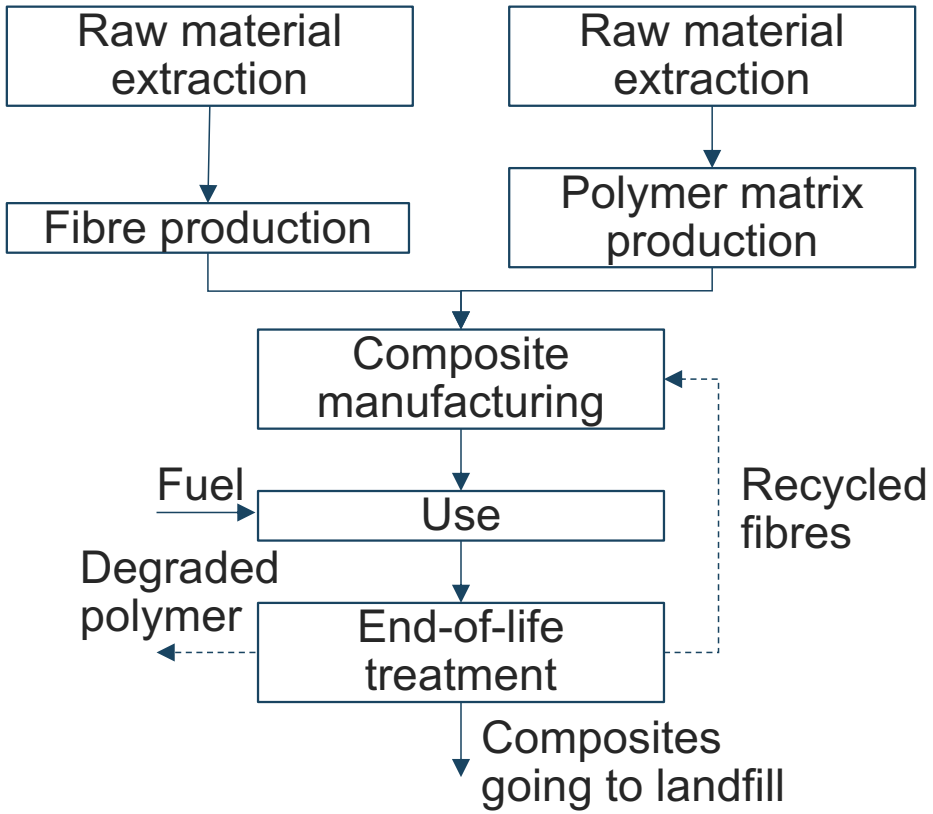
**Frida.hermansson@chalmers.se*

Background/introduction

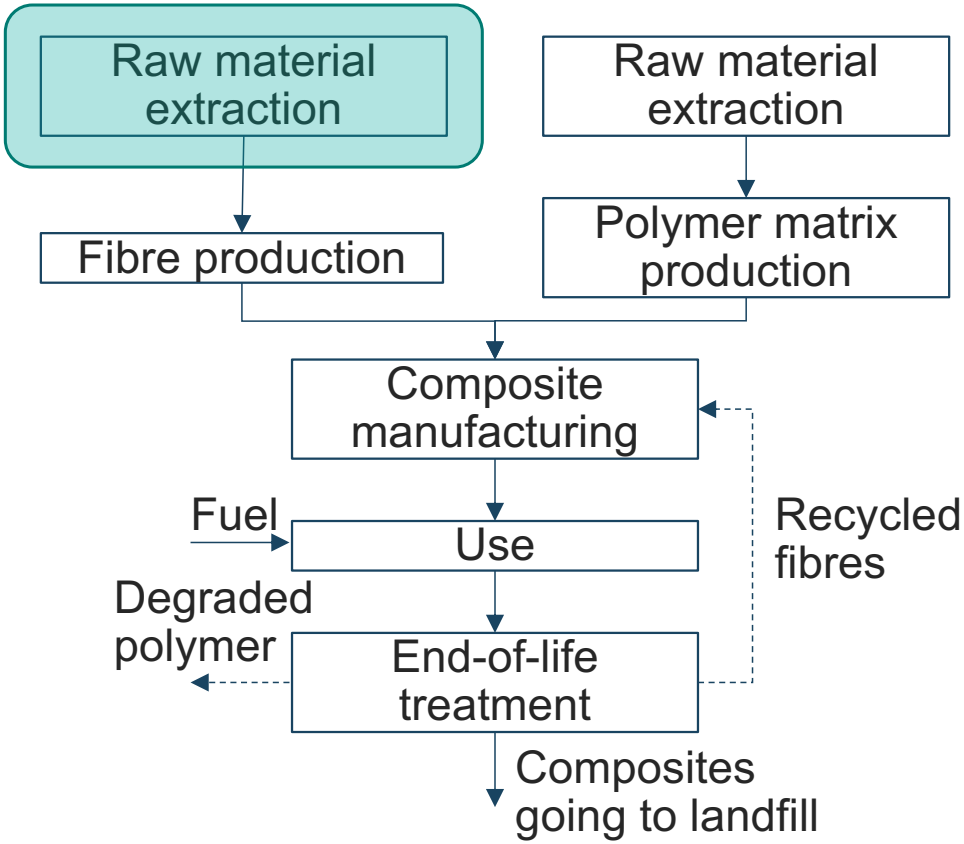
- Work was carried out within the LIBRE project-Lignin based carbon fibres for composites
- Carbon fibre composites are often used in vehicles for their lightweighting properties
  - Compared to using fibreglass, this does not automatically decrease the life cycle environmental impact [1]
  - The carbon fibre production is often the hotspot for carbon fibre composites [1]
- Three routes that could reduce the environmental impacts of carbon fibre composites are:
  - The use of bio-based raw materials
  - The use of microwave technology in carbonization
  - The recycling of composites and recovery of fibres
- This study assesses the environmental impact of these three routes and if they can make carbon fibre composites (aka CFRP) in vehicles environmentally competitive to fibreglass (aka GFRP)

[1] Hermansson, F., M. Janssen, and M. Svanström, Prospective study of lignin-based and recycled carbon fibers in composites through meta-analysis of life cycle assessments. Journal of Cleaner Production, 2019. ***223****: p. 946-956.*

Basic outline of the composite life cycle when used in a vehicle



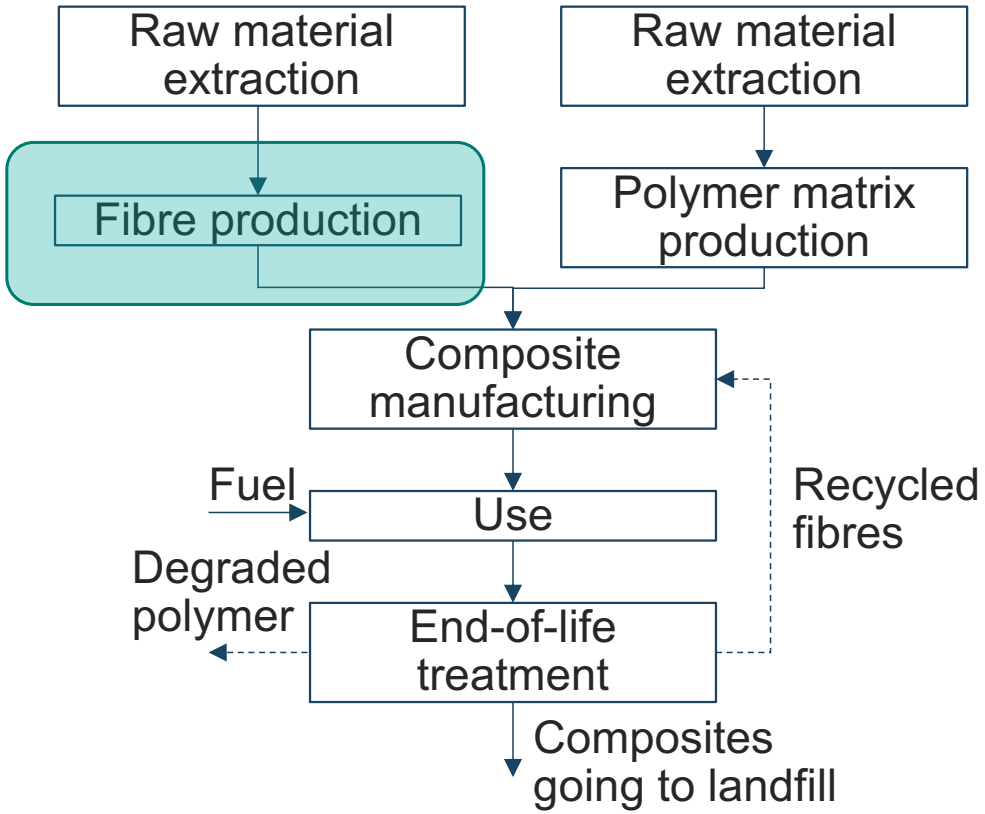
Route 1: The use of bio-based raw materials



Route 1: The use of bio-based raw materials

- Carbon fibres can be produced from lignin instead of fossil based polyacrylonitrile (PAN)
  - Lignin is a macromolecule found in wood
  - A by-product from the pulping industry and biorefineries
- **Not** applicable to glass fibre production

Route 2: The use of microwave technology in carbonization

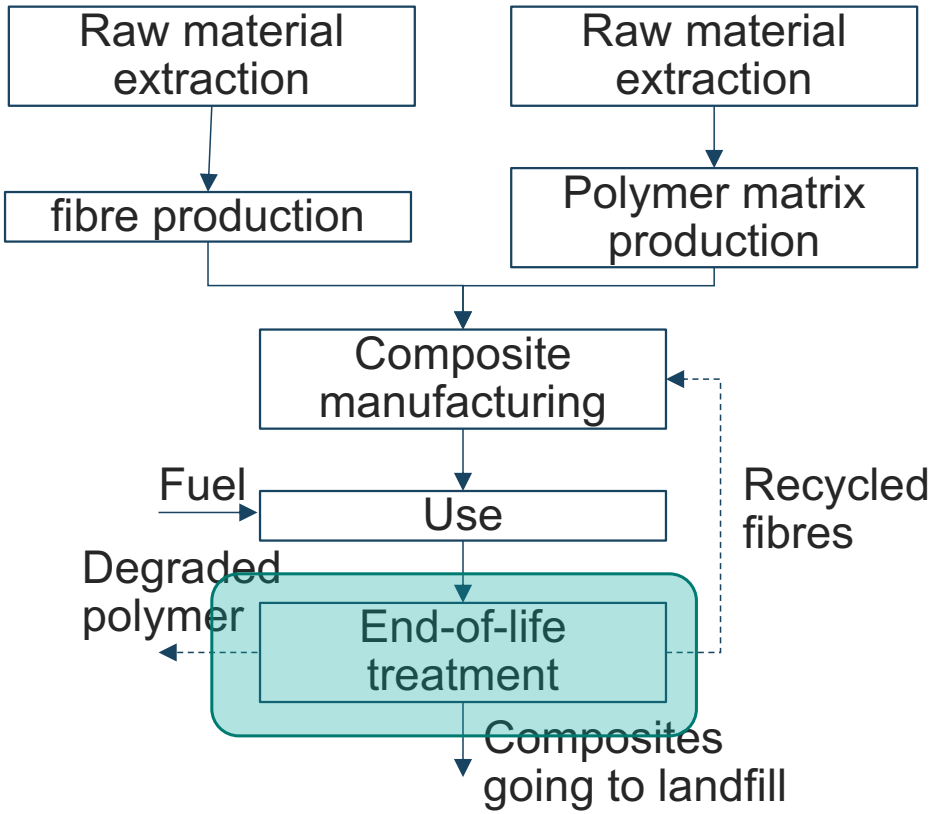


Route 2: The use of microwave technology in carbonization

- Microwave technology instead of conventional furnaces can be used to decrease the energy use in carbon fibre production
- Can decrease energy consumption with more than 90% as suggested by Lam et al. [2]
  - This is connected to a fast heating rate and a short process time
- **Not** applicable to glass fibre production

[2] Lam, S.S., et al., Cleaner conversion of bamboo into carbon fibre with favourable physicochemical and capacitive properties via microwave pyrolysis combining with solvent extraction and chemical impregnation. Journal of Cleaner Production, 2019. ***236****: p. 117692.*

Route 3: The recycling of composites and recovery of fibres



Route 3: The recycling of composites and recovery of fibres

- Composites can be recycled by means of, for example, pyrolysis, grinding, or super critical water dissolution
  - Liberates the fibres with some tenisle strength reduction
  - Polymer can be recovered to various extent depending on method
- Applicable to **both** carbon fibre composites and fibreglass

LCA goal and scope

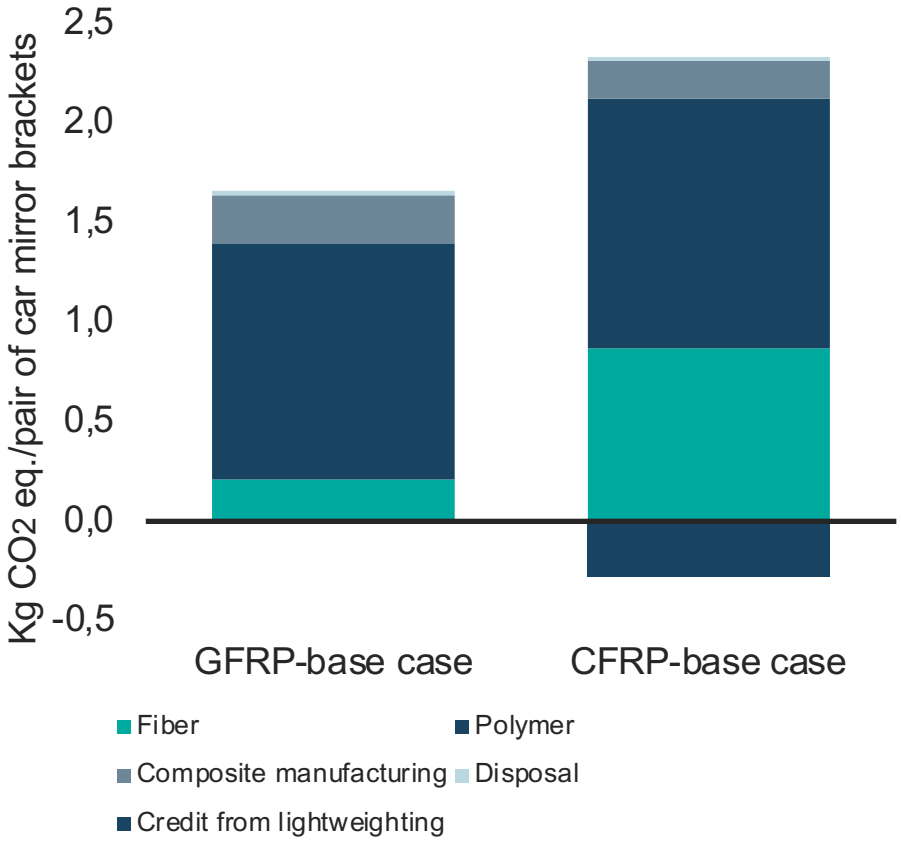
- Functional unit: 1 pair of car mirror brackets used for 100 000 km
  - Produced from either fibreglass (0.24 kg) or carbon fibre composites (0.19 kg)
    - Fibreglass: 40% fibre and 60% polyamide
    - Carbon fibre composite: 20% fibre and 80% polyamide
- Cradle-to-grave study
  - Composites are assumed to be sent to landfill after use if not recycled
- The vehicles with carbon fibre composite mirror brackets are given a credit for avoided fuel use due to lightweighting
- All composites are assumed to be produced from primary materials
- Impact categories: Climate impact and cumulative energy demand

LCA goal and scope

- Three technology development routes were assessed
  1. Lignin-based carbon fibre in composites
     - Fibres assumed to be made from 50% lignin and 50% bio-polyurethane
     - Economic allocation for distributing impacts of biorefinery in lignin production
     - We assumed 50% material yield in stabilization and carbonization
  2. PAN-based carbon fibres produced by means of microwave technology in composites
     - We used a proxy value of an energy reduction of 93.5% based on data by Lam et al. [2]
     - We assumed 50% material yield in stabilization and carbonization
  3. The recycling of the composites by means of pyrolysis after use
     - Using the end-of-life recycling approach as suggested by Hermansson et al. [3]
       - Considers the tensile strength reduction for quality degradation
     - 100% recycling rate

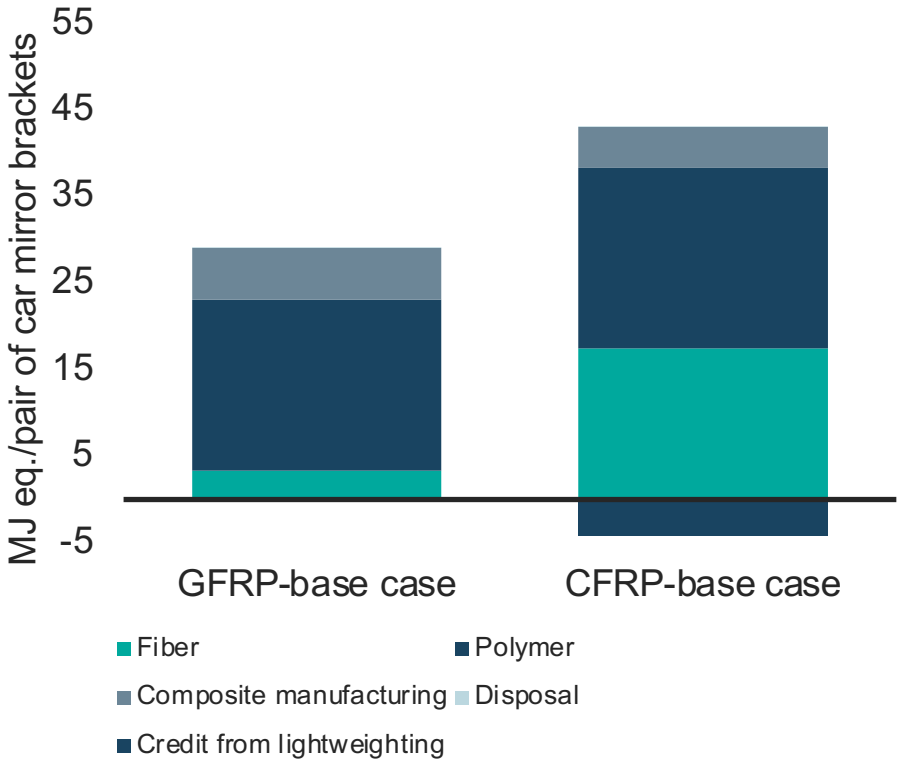
[3] Hermansson, F., et al., Allocation in recycling of composites-the case of carbon fibre reinforced polymers. Manuscript in Progress, 2021.

Results - Climate impact



Case	GFRP impact	CFRP impact
Base case	1	+23%
1. Using bio-based raw materials	±0%	+7%
2. Using microwave tech. in carbon fibre production	±0%	+4%
3. Recovery of fibres at end-of-life	+69%	+39%

Results- Cumulative energy demand



Case	GFRP impact	CFRP impact
Base case	1	+34%
1. Using bio-based raw materials	±0%	+20%
2. Using microwave tech. in carbon fibre production	±0%	+15%
3. Recovery of fibres at end-of-life	+49%	+21%

Conclusions

- Microwave technology and the use of bio-based raw materials routes show potential for decreasing the relative environmental impacts of carbon fibre composite
  - However the env. impact of carbon fibre composites is still higher than for fibreglass
- Only one route results in lower env. impact than fibreglass: Recycling of composites and recovery of fibres
  - This is very dependent on the allocation approach used
  - Recovery of high quality products is important!
- Fibre production is a hotspot!
  - Would a combination of recycling of bio-based carbon fibres produced by means of microwave technology be possible?
  - What would the quality of recycled bio-based carbon fibres be?

Acknowledgement

- This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 720707.

CHALMERS